United States Coast Guard

PROCESS IMPROVEMENT GUIDE

Total Quality Tools for Teams and Individuals

Second Edition

January 1994

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Preface to Second Edition

ABOUT THIS GUIDE...

The Quality Center Staff wishes to thank each of you who called or wrote to give us your ideas for improving the Process Improvement Guide. While no one book can answer all the questions or situations that may come up as you try to implement Total Quality, we have tried to use as much of your feedback as possible.

Hopefully, we've done a good job of listening and this edition will prove more "user friendly" than the original. Over 10,000 copies of the first edition have been distributed throughout the Coast Guard. It is being used to conduct Quality Awareness courses, by workgroups and QATs involved in problem-solving and improvement activities, and in the Measurement courses. It has proven useful to Coast Guard members at all types of units and levels of command.

Successful implementation of the principles and practices of TQM will continue to require each of us - from Flag Officer to Seaman - to be "continuous learners." We have to keep challenging our basic assumptions about how we perform our day-to-day jobs. We need to constantly ask ourselves, "Why?"

Adopting the philosophy of TQM requires teamwork. ***You cannot do Quality alone!*** We encourage you to share your lessons learned, resources, books and talents with one another.

Good Luck! We'll be looking for you somewhere along the journey to Quality.

the Quality Center Staff

Section 1

OVERVIEW OF PROCESS IMPROVEMENT

Adopting the philosophy of TQM requires each of us to make a shift in how we look at the work we do. Too often, we focus only on those things we are directly involved in and never stop to ask ourselves, " Is this the right thing to do or the right way to do it?"

TQM asks us to do just that - **every day**. It asks us to challenge our basic assumptions about how we do our jobs. We must look at ways we can continually improve our individual efforts, to add increased value to the process, and satisfy our customers.

To improve any work process we must:

- ✔ **Clearly define the current work process**
- ✔ **Measure the process's effectiveness and efficiency**
- ✔ **Determine if it is a stable/unstable process**
- ✔ **Avoid "tampering" with the process**
- ✔ **Eliminate "special" causes of variation in the process**
- ✔ **Reduce "common" causes of variation in the process**
- ✔ **Continually look for improvement opportunities**

This chapter presents some useful models and techniques for taking a systematic approach to process improvement. They will help you discover both what is the right thing to do and the right way to do it. They will help you tap into your biggest improvement resource -*your customer!*

The rest of the Process Improvement Guide will present information and tools to help you collect and gather data, convert that data into useful decision-making information, and work together more efficiently and effectively on your improvement or problem-solving projects.

Overview

For most Quality experts, taking a systematic approach to process improvement begins with the PDCA (Plan, Do, Check, Act) Cycle developed by Dr. Walter A. Shewhart. The goal of progressing through each step of the cycle is to achieve Quality of goods, products, services, or information *-as defined by the customer!*

There are many definitions of Quality:

"Fitness for use"

JOSEPH JURAN

"Whatever the buyer says it is"

A.V. FEIGENBAUM

"Right Things Right"

ODI*

"Zero defects, conformance to requirements"

PHILLIP CROSBY

"Predictable uniformity, dependability at low cost, suited to market."

W. EDWARDS DEMING

"The totality of features and characteristics of a product that bear on its ability to satisfy a given need."

AMERICAN SOCIETY OF QUALITY CONTROL

Whatever YOUR definition of Quality, you cannot achieve Quality without improving your processes. Improving processes requires a patient, systematic approach. Each step builds on the one before it, reinforcing the information obtained and allowing you to develop a "doable" action plan.

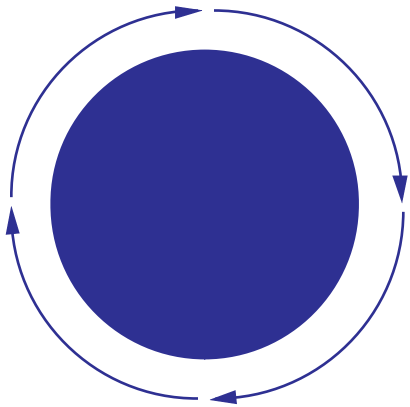
***ODI - Organizational Dynamics, Inc** -The initial TQM implementation consultant and trainer for the Coast Guard. Their Quality Blueprint, FADE problem-solving model, and other key concepts are presented here since many Coast Guard members may be familiar with them or have received some initial training in their use.

THE SHEWHART CYCLE (PDCA or Deming Cycle)

Overview

What it is:

The Shewhart Cycle provides us with a systematic approach to achieving continuous improvement. It is represented graphically as a circle or wheel because it involves repeating the steps over and over in a continuous effort to improve your processes. The circle has four quadrants: PLAN, DO, CHECK and ACT.



How to use it:

To use the Shewhart Cycle properly, follow the five steps listed below.

Plan a quality improvement. Study your current work process and available data. Decide what you want to do and how best to do it.

Do the activity planned. Put your improvement or problem-solving plan into effect. Train and equip those responsible for accomplishing the task.

Check the results. Measure the results of your actions. Analyze your data.

Act on the results. If the effort was truly an improvement, standardize and document it. If it wasn't successful, abandon the plan or adjust it as needed to overcome any identified weaknesses or problems.

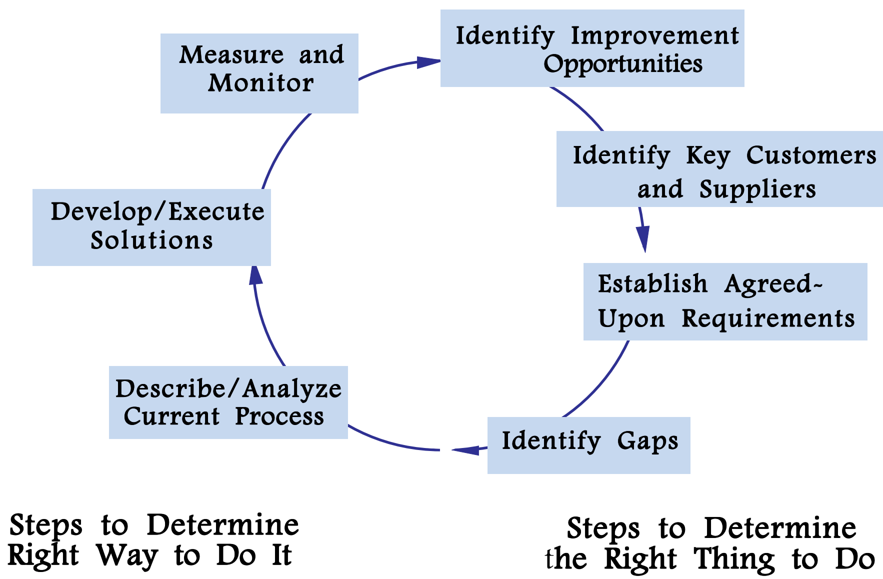
Repeat. Using your data and lesson learned, continue around the cycle again by planning and carrying out further process improvement activity.

Overview

THE QUALITY BLUEPRINT

What It Is:

A model for process improvement, the Quality Blueprint examines both what you do and how you do it. By following the steps below in sequence, you help ensure suppliers, customers and participants in your work processes are all included in your efforts to continuously improve. Following the Quality Blueprint helps prevent the all too natural tendency to jump to solutions prior to really understanding a problem or its root causes.



How to Use It:

The Quality Blueprint will allow you to decide what area you should focus your improvement efforts in, what customers and suppliers you need to establish product, service or information requirements with, and how your current process will (or will not) allow you to meet those requirements. It walks you through the improvement cycle. More information on the individual steps in this cycle is provided on the following pages.

THE RIGHT THING

Identify opportunity:

- Listen to your customers
- Look at current measures
- Identify avoidable costs
- Identify non-value added steps
- Set Priorities

Identify key customers and suppliers

- Ask, "Who gets my output?"
- Ask, "Whose inputs do I need?"
- Determine your critical customers/suppliers

Establish Agreed-Upon Requirements

- Ask your customers:
  What do you need from me?
  What do you do with it?
  Are there any gaps?
- Set priorities for action

Identify Gaps

- Identify gaps in current process
- What data do you need/have to verify gaps exist?

THE RIGHT WAY

Describe current process

- Flowchart your current process
- Look for bottlenecks
- Identify non-value added steps
- Look for root causes

Develop/Execute Solutions

- Generate alternatives
- Validate feasibility
- Develop an Action Plan
- Implement solution

Measure/Monitor Results

- Establish measures
- Establish feedback systems
- Document results
- Continue improvement activity

The Quality Blueprint will help you keep a process-focused view of Quality improvement and will allow you to better meet your current customer needs while at the same time building a stronger customer-supplier chain for future efforts.

Overview

THE FADE PROBLEM-SOLVING PROCESS

What It Is:

A four step problem-solving model, the FADE process can be useful for individuals, Quality Action Teams (QAT), Natural Workgroups (NWG), or others who have been tasked with developing solutions to a problem.

FOCUS: Choose a problem

- Generate a list of problems
- Select ONE problem
- Verify and define that problem

ANALYZE: Learn about the problem

- Decide what you need to know
- Collect data - baselines and patterns
- Determine root causes and most influential factors

DEVELOP: Create a solution

- Generate a list of promising solutions
- Select ONE solution
- Develop an implementation plan

EXECUTE: Implement, monitor, adjust

- Gain necessary commitment to your plan
- Execute your plan
- Monitor the impact(s)

How to Use It:

FADE requires you to properly complete the outputs required by a each step before you move on to the next. Failure to do so can doom your attempt to solve a problem or minimize the quality of recommended solutions. You ***must*** collect and properly analyze appropriate types and amounts of data during each step..

REQUIRED OUTPUTS FOR F.A.D.E. PROCESS

FOCUS - A written problem statement detailing:

- The current state of your process (What is happening now)
- The negative impacts of that state (Why change is needed)
- Your desired state (What you want to happen)
- The impacts of achieving your desired state (Benefits)

ANALYZE -Verified problem statement/list of "root" causes

- A flowchart of your ***current*** work process
- A list of "root" causes for problems/gaps identified

DEVELOP - List of proposed solutions/Action Plan

- List of recommended solutions
- Action Plan to implement your solutions
- Who, What, When, Where, Why and How of your plan
- Appropriate documentation to explain/justify recommendations

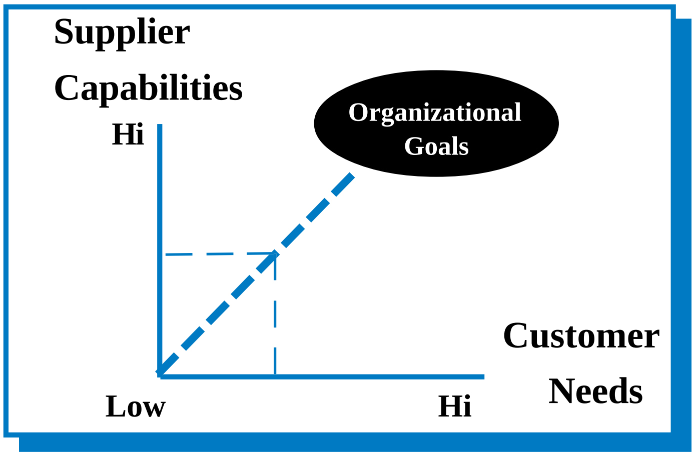
EXECUTE - Process and Results Measures

- Measures of process efficiency/effectiveness
- Data collection/monitoring plan

OTHER KEY QUALITY CONCEPTS

ALIGNMENT: Matching your capabilities/customer needs with organizational goals

Alignment can be achieved by meeting with your customer, establishing agreed-upon performance requirements, and then adjusting your work processes to meet those requirements and assigned organizational goals. It also includes measuring, monitoring and continuous feedback to your customers, suppliers, and those working in your process.



WORK AS A PROCESS: Your work is part of an interrelated process

Your work efforts are part of a process, not an isolated event. The critical part of any process is for each individual - whatever role they are playing - to ensure what they are doing *adds value* to the ultimate product, service, or information that is the output of that process.

OTHER KEY QUALITY CONCEPTS (CON'T)

RIGHTTHINGS RIGHT: Meeting our customer's needs

Doing the Right Things Right is the target for our Quality efforts. In trying to accomplish that, our work efforts can generally fall into one (or more) of the following categories:

Right Things Right - Things we should do and we do well

Right Things Done Wrong - Things we should do but don't do well

Wrong Things Done Right - Things we shouldn't do but do well anyway

Wrong Things Done Wrong - Things we shouldn't do and do poorly

FIVE PILLARS: Key elements of a Quality organization

A Quality initiative within any organization needs the following five "support" pillars:

Customer Focus - Aligning all your processes to meet customer needs

Total Involvement - Getting everyone involved in improving processes

Systematic Support - Aligning organizational systems with Quality principles and practices (i.e. budget, evaluations)

Measurement - Establishing performance requirements and monitoring

Continuous Improvement - Never settling for "good enough"

OTHER KEY QUALITY CONCEPTS (CON'T)

COSTS OF QUALITY: Necessary and avoidable costs of Quality

Costs of Quality can account for as much as 30% of a budget. Some of these costs are avoidable (rework) and some are necessary (training). Types of cots associated with Quality might include:

INTERNAL FAILURE

Costs of failing to do it right the first time

EXTERNAL FAILURE

Similar to above, but also costs to investigate complaints and penalty payments, etc.

APPRAISAL

Costs to see if we did do it right the first time (inspection)

PREVENTION

Costs of trying to ensure we do it right the first time (quality)

INDIRECT

Price paid by customer to fix what we didn't do right the first time

STRATEGIC QUALITY GOAL: Coast Guard-wide goal for Quality

We will deliver high quality service to the American Public by all Coast Guard people continuously improving our processes to meet the ever-changing needs of our customers.

Section 2

GENERATING IDEAS AND IDENTIFYING OPPORTUNITIES

One of the cornerstones of any Quality initiative is getting as many people as possible involved in your improvement efforts. People get excited about contributing to the effort to make things better. Especially when it is *their* work area or processes being improved! When an environment has been established where people believe something will really be done with their ideas, contributions tend to flow fast and free.

Generating ideas, organizing the information gathered , and then identifying opportunities for improvement is crucial to successful implementation of Quality management practices. The tools and techniques presented in this section will help you in this important task.

TOOLS AND TECHNIQUES IN THIS SECTION

BRAINSTORMING

What it is:

Brainstorming is a technique, generally used in a group setting, to quickly generate a large number of ideas about a specific problem or topic. It can help you:

- Encourage creative thinking and generate enthusiasm
- Encourage participation and building on the ideas of others
- Avoid the "paralysis of analysis" by not evaluating ideas

How to do it:

The goal of brainstorming is to ***generate*** ideas. Before you start, make sure everyone in your group understands the importance of *postponing* judgments until after the brainstorming session is completed.

- Write the problem or topic on a blackboard or flipchart where all participants can see it
- Write *all* ideas on the board and do as little editing as possible
- Number each idea for future reference
- There are several brainstorming techniques: structured brainstorming, free-form brainstorming, or silent brainstorming

In structured brainstorming (One-at-a-time method):

- Solicit *one* idea from each person in sequence
- Participants who don't have an idea at the moment may say "pass"
- A complete round of passes ends the brainstorming session
- The *advantage* of structured brainstorming is that each person has an equal chance to participate, regardless of rank or personality

  The *disadvantage* of structured brainstorming is that it lacks spontaneity and can sometimes feel rigid and restrictive

In unstructured (or Open-door) brainstorming:

- Participants simply contribute ideas as they come to mind.
- The *advantage* of free-form brainstorming is that participants can build off each other's ideas. The atmosphere is very relaxed.
- The *disadvantage* of free-form brainstorming is that the less assertive or lower ranking participants may not contribute.

An ideal approach is to combine these two methods. Begin the session with a few rounds of structured brainstorming and finish up with a period of unstructured brainstorming.

In silent (or Write-it-down) brainstorming:

- Have participants write ideas individually on sticky-back notes or small slips of paper.
- Collect the papers and post them for all to see.
- The *advantage* of silent brainstorming is that it prevents individuals from making disruptive "analysis" comments during the brainstorming session and provides confidentiality. It can help prevent a group from being unduly influenced by a single participant or common flow of ideas.
- The *disadvantage* of silent brainstorming is that the group loses the synergy that comes from an open session.

Silent brainstorming is best used in combination with other brainstorming techniques.

The result of a brainstorming session is a list of ideas. If this list is too long, the group can boil it down using one of the decision-making tools described later in this section.

Points to remember about Brainstorming:

Never judge ideas as they are generated. The goal of brainstorming is to generate a lot of ideas in a short time. Analysis of these ideas is a separate process, to be done later.

Don't quit at the first lull. All brainstorming sessions reach lulls, which are uncomfortable for the participants. Research indicates that most of the best ideas occur during the last part of a session. Try to encourage the group to push through at least two or three lulls.

Try to write down all of the ideas exactly as they were presented. When you condense an idea to one or two words for ease of recording, you are doing analysis. Analysis should be done later.

Encourage outrageous ideas. While these ideas may not be practical, they may start a flow of creative ideas that can be used. This can help you break through a lull.

Try to have a diverse group. Involve process owners, customers, and suppliers to obtain a diverse set of ideas from several perspectives.

Generating Ideas and Identifying Opportunities

After Brainstorming:

Reduce your list to the most important items

Combine items that are similar

Discuss each item - in turn - on its own merits

Eliminate items that may not apply to original issue or topic

Give each person one final chance to add items

Brainstorming is a FUN way to generate a lot of ideas quickly. Because it is simple and easy to use, however, don't lose sight of the fact it can be a very powerful tool!

FIVE WHYS

What it is:

Asking, "Why?" is a favorite technique of the Japanese for discovering the root cause (or causes) of a problem. By repeatedly asking the question, "Why?" (five is only arbitrary figure), you peel away layer after layer of "symptoms" to get to the real heart of an issue. You may never know exactly how many times you'll have to ask why. This technique helps you:

- Identify the root cause(s) of a problem
- See how different causes of a problem might be related

How to do it:

- Describe the problem in very specific terms
- Ask why it happens
- If the answer doesn't identify a *root* cause, ask why again. You know you've identified the root cause when asking why doesn't yield any more useful information
- Continue asking why until the root causes are identified. This may take more or less than five whys

Points to remember:

- Always focus on the process-aspects of a problem, rather than the personalities involved. *Finding scapegoats does not solve problems!*

Five Whys Example

A Commanding Officer wanted to know why the unit had failed its Training Readiness Evaluation (TRE) which is a necessary first step prior to going to Refresher Training.

CURRENT STATE: This unit failed its TRE

Why? We didn't pass enough of the evaluations/exercises

Why? The evaluations/exercises were different than we expected

Why? We had prepared using another cutter's checklists

Why? Our TRE checklists didn't arrive in time

Why? We never submitted our change of unit address for the Standard Distribution List (SDL) when we shifted homeport. Therefore, the checklists were mailed to the old address and had to be forwarded to our new address. We received them late.

At this point, several avenues for follow-up might become evident. The point here being not to fix blame but to correct the process that allowed this situation to occur. Many times a small, seemingly insignificant action can have some pretty major impacts and consequences.

SURVEYS AND INTERVIEWS

What are they:

Surveys and interviews are used to gather information from an identified target population. They are a feedback mechanism and, when properly designed and carried out, provide a great deal of usable information. They are especially useful when:

- Only a small amount of initial data is available
- Participation of an extended group is desirable
- Initial issues are unclear and in need of amplification/clarification
- It is important that others know an issue is being addressed

Generating Ideas and Identifying Opportunities

How they are used:

It is difficult for those not trained in sampling theory and techniques to design and process a high quality survey. However, the following guidelines should help.

- Clearly identify what information you need to collect
- Make it as simple and as easy as possible for people to participate
- Clearly identify to participants what you intend to do with their answers
- Identify how to complete, where, and when to return the survey
- Do a test run on a small pilot population to remove any "bugs"
- Design the survey so it will be easy for you to process its information
- As much as possible, conduct the survey/interview face-to-face
- Make it important to participants to return the survey/interview form
- Agree to publish your results in an appropriate time/manner
- ACT on the results!

Remember: ***Involve someone who is experienced in conducting surveys/interviews if possible. It will make for a better product, more useful information collected, and less stress and strain on you.***

THE THREE ALIGNMENT QUESTIONS

What are they:

The Three Alignment questions are used to generate information about how well your processes are currently meeting your customer's needs. To create a meaningful rapport and establish some agreed-upon performance requirements between all those involved in a particular process, ask these three simple questions .

How they are used:

After identifying those key customers involved in your work process, you begin by asking each:

> ***WHAT DO YOU NEED FROM ME?***
>
> ***WHAT DO YOU DO WITH WHAT I GIVE YOU?***
>
> ***WHAT ARE THE GAPS BETWEEN WHAT I PROVIDE AND WHAT YOU NEED?***

These questions will allow you to discover what your customer's needs, wants and expectations may be for the service, product or information you are supplying. Additionally, by understanding how your customer is using your output, you can better align your process capabilities with what your customer wants. Knowing if there are gaps ,and what the impacts of those gaps are for both you and your customer can provide a rich opportunity to meet your customer's needs.

Once you have generated this information by meeting with your customer(s), you will have some baseline data and a better idea of the direction in which you need to make improvement efforts. You can then organize the responses and prioritize (with the customer) those actions necessary to meet the customer's requirements.

You should also seek to establish a formal, repetitive feedback system to ensure you continue to obtain information on your efforts to meet your customer's needs.

THE CONTINGENCY DIAGRAM

What it is:

Using reverse logic, the Contingency Diagram is a way to generate ideas concerning an issue or concern. By thinking of all the ways you can cause a problem to get worse or continue unchecked, you provide the basis for later developing an action plan to overcome these barriers.

How to use it:

A Contingency Diagram can help you generate ideas from which you can develop those specific actions necessary to eliminate a problem or make an improvement. You use it by following these steps:

STEP ONE - Select a situation (either a goal or problem)

STEP TWO - Draw a Contingency Diagram (next page)

STEP THREE - Brainstorm:

What will cause this situation to get worse/continue
Think of things that will prevent your desired state
Follow the rules for brainstorming
Enter each action down on the Contingency Diagram

STEP FOUR - List specific actions to prevent these obstacles

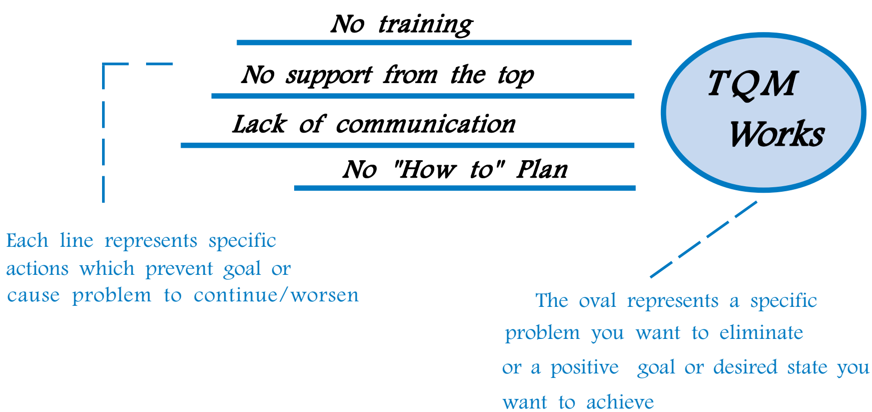
STEP FIVE - Use this list to develop an Action Plan

This can be a very powerful idea and solution generating tool. The key is to follow the rules of brainstorming and not judge, evaluate, criticize or praise others ideas while brainstorming. Once the group has exhausted its ideas on the topic, discuss and clarify the list which has been created.

The Contingency Diagram allows you to tap into the power of brainstorming and provides a convenient framework to organize your ideas. It also allows you to prioritize and generate further action based on those barriers to your desired state which you have creatively discovered.

THE CONTINGENCY DIAGRAM

Below is an example of a completed Contingency Diagram and the Prevention Checklist/Action Plan it generated.



Prevention/Action Checklist

A Prevention/Action Checklist can be developed by taking each obstacle identified and brainstorming ways to prevent it from happening. Below is an example using only one of the items identified above.

Obstacles	*Corrective Actions*
1. Lack of communication	*1. Publish TQM activity/"success" stories* *2. Develop mission statements* *3. Develop feedback loops/opportunities* *4. Conduct training in TQM (Both awareness and tools)*

Another good technique is to take each of the items you have identified as a barrier and put it into the oval and complete a separate Contingency Diagram. This allows for some specific action items and generates a tremendous amount of ideas.

MULTI-VOTING

What it is:

Multi-voting is a quick and easy way for a group to find the items of the highest priority in a list. This technique helps you:

- Prioritize a large list without creating a "win-lose" situation in the group that generated the list.
- Separate the "vital few" items from the "trivial many" on a large list.

How to do it:

Empower. Give each team member a number of votes equal to approximately half the number of items on the list (e.g., 10 votes for a 20-item list).

Vote. Have the members vote individually for the items they believe have high priority.

Compile the votes given to each item. You can put a mark beside each item for every vote it receives.

Select the top four to six items. Discuss and prioritize these items relative to each other. If you can't establish the top four to six, remove from the list the items that have the fewest votes and then conduct another vote.

Helpful hint:

Multi-voting is best suited for large groups and long lists. Its simplicity makes it very quick and easy to use.

Multi-Voting Example

District staff elements attended a lot of meetings at different locations around their district. They complained because meetings conducted at these locations were not always as productive as they might have been, so the Chief of Staff called a meeting to improve the situation. A brainstorming session produced the following list of reasons for unproductive meetings:

1. No agendas
2. No clear objectives
3. Going on tangents
4. Too much time
5. Too much protocol/politics
6. Wrong people
7. Not enough data provided before meeting
8. No administrative support
9. Roles of participants not clear

To reduce this list to a manageable size, each member was given five (05) votes (approximately half of the total number of items).

The problems received the following votes:

1. ////
2. //
3. ///
4. ///// /////
5. ///
6. /////
7. ///// ///// ////
8. //
9. ///// ///

The group then decided to focus on problems 7, 4, and 9.

NOMINAL GROUP TECHNIQUE

What it is:

Nominal group technique is a structured method that a group can use to prioritize items in a list. This method uses priorities of each group member to discover the overall priorities of the group. Nominal group technique helps you:

- Prioritize a list of ideas.
- Make decisions using inputs from *all* participants.

How to do it:

Assign a letter to each idea. For example, for eight ideas, you would assign the letters A through H.

List the letters. Have each person in the group write the assigned letters on a piece of paper.

Prioritize the lists. Have each person prioritize their list by writing a number beside each letter. If there are eight ideas, then "8" is written beside the letter corresponding to the most important idea. This is repeated for each number until "1" is written beside the letter corresponding to the least important idea. Each number (1 through 8) is used *only once* by each group member.

Compute the group total for each letter. The letter with the highest score is the idea with the highest priority, and the letter with the lowest score has the lowest priority.

Nominal Group Technique Example

The following office problems were identified in a brainstorming session:

A. Ineffective organizational structure.

B. Poor communications outside the office.

C. Lack of training.

D. Poor communications within the office.

E. Unclear mission and objectives.

F. Poor distribution of office mail.

G. Lack of feedback on reports on management.

Each group member then wrote the letters A through G on a piece of paper and prioritized each problem from 1 to 7 (lowest to highest), using each number only once. The results were summarized as follows:

Problem	***Person***					***Total***	***Priority***
	1	***2***	***3***	***4***	***5***		
A	6	5	7	5	6	29	#2
B	3	2	4	1	3	13	#5
C	1	1	2	2	2	[redacted]	
D	4	4	5	6	4	23	#4
E	7	7	6	7	5	[redacted]	
F	2	3	1	3	1	10	#6
G	5	6	3	4	7	25	#3

FORCE FIELD ANALYSIS

What it is:

Force field analysis is a technique that helps you identify and visualize the relationships between the significant forces that influence a problem or goal. You can use it to:

- Identify key factors (forces) that promote or hinder the solution of a problem or the achievement of a goal.
- Identify improvement opportunities.

How to do it:

Define the objective. Clearly identify the problem or goal to be analyzed.

List the forces. List the key factors that promote or hinder the achievement of your goal or the resolution of your problem. Groups should use an idea-generation technique from Section 2 to do this. Use two lists: one for promoting forces and one for hindering forces.

Prioritize. Prioritize the forces in each list according to their relative impact on the problem or goal. You can use nominal group technique or some other decision-making tool.

Implement. Minimize or weaken the hindering forces and maximize or strengthen the promoting ones.

Goal: Quit Smoking

Promoting Forces		***Inhibiting Forces***
better health →		← habitual behavior
save money →		← need for nicotine
won't have to leave building every half hour →		← need to have fingers occupied
family won't breathe smoke →		← need to have something in mouth
food will taste better →		← gain weight every time I try to quit

PAIRWISE RANKING

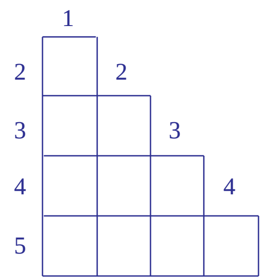
What it is:

Pairwise ranking is a structured method for ranking a small list of items in priority order. It can help you:

- Prioritize a small list.
- Make decisions in a consensus-oriented manner.

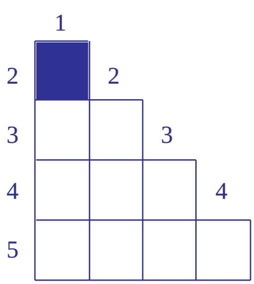
How to do it:

Construct a pairwise matrix. Each box in the matrix represents the intersection (or pairing) of two items. If your list has five items, the pairwise matrix would look like this, with the top box representing idea 1 paired with idea 2:

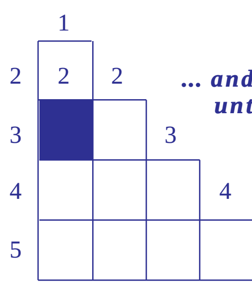


Rank each pair. For each pair, have the group (using a consensus-oriented discussion) determine which of the two ideas is preferred. Then, for each pair, write the number of the preferable idea in the appropriate box. Repeat this process until the matrix is filled.

1 and 2 compared: 2 is better.

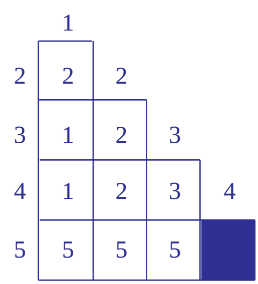


1 and 3 compared: 1 is better.



… and so on until…

4 and 5 compared: 5 is better.



Count the number of times each alternative appears in the matrix.

Alternative 5 appears 4 times in the matrix.

Alternative	1	2	3	4	[redacted]
Count	2	3	1	0	[redacted]
Rank					

Rank all items. Rank the alternatives by the total number of times they appear in the matrix. To break a tie (where two ideas appear the same number of times), look at the box in which those two ideas are compared. The idea appearing in *that* box receives the higher ranking.

Alternative 5 ranks 1st overall.

Alternative	1	2	3	4	[redacted]
Count	2	3	1	0	[redacted]
Rank	3rd	2nd	4th	5th	[redacted]

Pairwise Ranking Example

A QAT was asked to recommend sites for testing a pilot program of their recommendations. A feasibility study produced a list of six possible locations. The team then used pairwise ranking to determine that ATTC Elizabeth City, NC was best suited for this particular test.

1. TRACEN Petaluma
2. RTC Yorktown
3. TRACEN Cape May
4. ATTC E-City
5. ATC Mobile
6. Academy

	1	2	3	4	5
2	2				
3	1	3			
4	[redacted]				
5	5	5	5	[redacted]	
6	1	6	6	[redacted]	5

Site	1	2	3	[redacted]	5	6
Count	2	1	1		4	2
Rank	3rd	6th	5th		2nd	4th

Generating Ideas and Identifying Opportunities

AFFINITY DIAGRAM

What it is:

An affinity diagram is a technique for organizing verbal information into a visual pattern. An affinity diagram starts with specific ideas and helps you work toward broad categories. This is the opposite of a cause and effect diagram, which starts with the broad causes and works toward specifics. You can use either technique to explore all aspects of an issue. Affinity diagrams can help you:

- Organize and give structure to a list of factors that contribute to a problem.
- Identify key areas where improvement is most needed.

How to use it:

Identify the problem. Write the problem or issue on a blackboard or flipchart.

Generate ideas. Use an idea-generation technique from Section 2 to identify all facets of the problem. Use index cards or sticky-back notes to record the ideas.

Cluster your ideas (on cards or paper) into related groups. Use questions like "Which other ideas are similar?" and "Is this idea somehow connected to any others?" to help you group the ideas together.

Create affinity cards. For each group, create an affinity card, a card that has a short statement describing the entire group of ideas.

Cluster related affinity cards. Put all of the individual ideas in a group under their affinity card. Now try to group the affinity cards under even broader groups. You can continue to group the cards until your definition of "group" becomes too broad to have any meaning.

Create an affinity diagram. Lay out all of the ideas and affinity cards on a single piece of paper or a blackboard. Draw outlines of the groups with the affinity cards at the top of each group. The resulting hierarchical structure will give you valuable insight into the problem.

Affinity Diagram Example

A publication team wanted to reduce the number of typographical errors in their program's documentation. As part of a first step, they conducted a brainstorming session that produced the following list of factors that influenced errors.

Computers
Printers
Lighting
Comfort
Technical Jargon
Grammar
Draft Copy
Font
Computer Skill
No Feedback
Unreasonable Deadlines
Typewriters
Desk Height
Interruptions
Slang
Punctuation
Final Copy
Typing Skill
Proofreading Skill
Noise
Chair Height
Time of Day
Handwriting
Spelling
Distribution
Editing Skill
No Measurement

The following affinity diagram helped them to focus on areas for further analysis.

Typographical Errors

Environment

Interruptions

Unreasonable Deadlines

Time of Day

- **Ergonomics**
  - Noise
  - Lighting
  - Desk Height
  - Chair Height
  - Comfort

Equipment

Computers
Printers
Typewriters

Original Document

- **Author Skill**
  - Handwriting
  - Grammar
  - Punctuation
  - Spelling
- **Requirements**
  - Draft Copy
  - Final Copy
  - Distribution
  - Font

Technical Jargon
Slang

Training

Typing Skill
Editing Skill
Computer Skill
Proofreading Skill

No Definition of Quality

No Measurement
No Feedback

TIPS FOR KEEPING IDEAS FLOWING

Use 3x5 cards or Post-It notes to record your ideas: *This allows you to cluster similar thoughts, eliminate duplications and use a "silent" version of any of the techniques listed in this section. This can be helpful when issues carry a lot of emotion or there seems to be little interest in consensus.*

Be creative! *Don't limit suggestions or ideas early on in discussions. Encourage people to think "outside the box." Play "What If" and try to visualize the desired state IF you could do anything you wanted. Play "If I were the Commandant..."*

Focus on YOUR processes: *Improving Quality is a personal thing. The focus of your improvement efforts should be those things which are "broken" in your work area or those which seem to you to be the most inefficient/ineffective.*

During your brainstorming sessions:

Change seats*....views can be affected by where you sit in relation to others*

Avoid cliques*...encourage people to sit with those they don't work with*

Review the data or ideas periodically *- encourage further inputs*

Rotate groups (and/or members) *to provide a fresh perspective*

Make it clear you want EVERYONE to participate!

Create a climate where it is O.K. to disagree

Work to develop a group consensus

Don't evaluate...concentrate on getting quantity of ideas

HAVE FUN!

Section 3

DATA AND DATA COLLECTION

Overview:

Improving your decision making process through the appropriate use of data and learning to collect the right data are crucial Quality skills. By using the tools and techniques in this section, you will be able to gather data that will be meaningful to you and useful in your improvement efforts.

Inside This Section:

What is Data?

Basically, it is the numerical facts and figures which contain the information you will need to form conclusions or make your decisions. Data will generally be presented in descriptive or quantitative form.

Types of Data

MEASUREMENT DATA (Measurements)	Data resulting from a physical measurement Example: Distance, time, weight, etc. (Also known as Measurement or Continuous Data)
ATTRIBUTES DATA (Traits)	Data resulting from a count of units possessing particular characteristics or from a count of the occurrences of those characteristics themselves. (Also called Discrete Data) Example: No. of typos per page, Good/Bad.

Why Collect Data?

- To provide a foundation to "sell" proposed solutions or other actions to those in decision-making positions
- To serve as the basis for timely action (or appropriate non-action)
- To enable you to focus on the real reasons for problems, not just assumptions, symptoms, or "gut" feelings
- To communicate the situation/issues more accurately and effectively
- To allow you to methodically examine the relationship between the occurrence of an event and its cause(s)
- To provide the basis for process control and improvement
- To form a legally valid basis for acceptance or rejection of vendor-supplied items
- To justify or validate opinions or beliefs, even ones long-held or taken for granted.

Five Elements of Useful Data

To be most useful, your data should contain all of these essential elements:

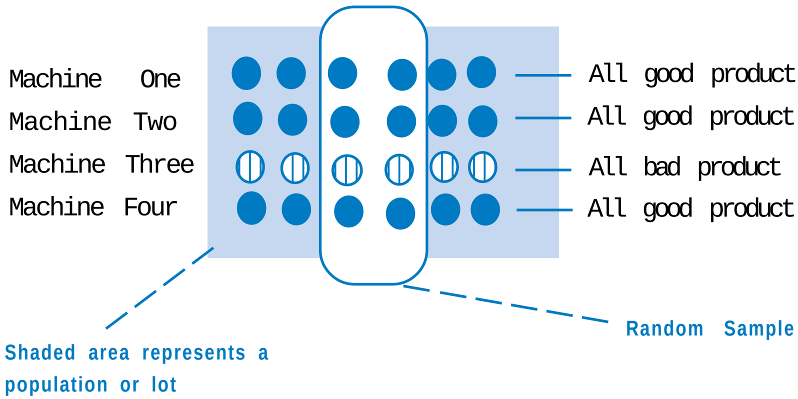
- Data should be collected in a timely manner
- Data should be collected in a consistent manner
- Data should be related to your process or the issue being examined
- Data should be accurate
- Data should be precisely defined (definitions should be agreed-upon by all process participants, i.e.. Supplier/Customer/Process Worker)

Sampling

Sampling is a technique used to estimate , with a statistical degree of confidence, information concerning a process where measuring or counting the outputs of the entire process is impractical or too expensive. A collection or set of individuals, objects, or measurements whose properties or characteristics are to be analyzed is called a "population." Sampling is merely "surveying" a portion of that population.

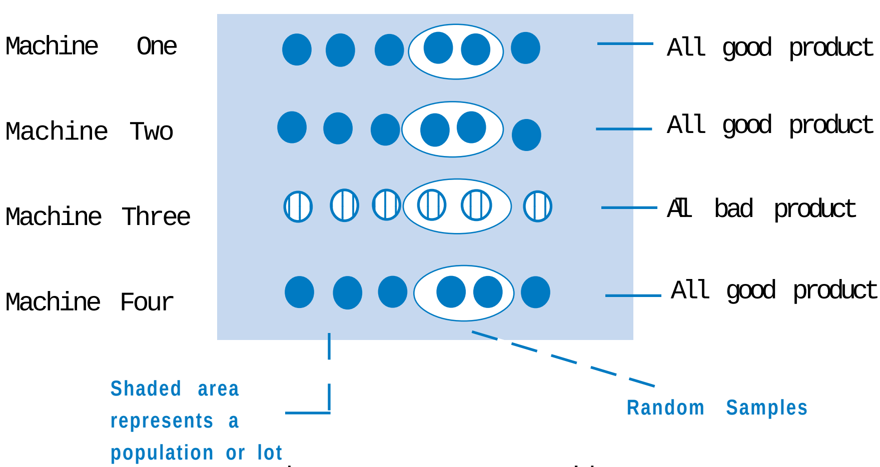
When sampling, it is crucial that a representative portion of the population be selected. A good method for doing this is to use a RANDOM SAMPLE. While a lot could be said here concerning random sampling, the essential point to remember is that a sample can be described as random if each member of the population had <u>an equal chance</u> of being included in the sample.

Stratified Random Sampling is similar to regular random sampling, except that the population or lot sampled is divided into subsections (also called strata or layers) which should be as similar as possible. The following will illustrate the advantage of stratified random sampling.



An unstratified random sample could lead us to conclude that our machines are producing 25% BAD product, and that we therefore need to perform some kind of maintenance or inspection on ALL of them.

To prevent misreading our process this way, we can utilize a stratified random sample. Basically, it would look this way:



As you can see, a random sample comprised of one unit from each of the four layers clearly shows that three machines are producing good product and that only one is not. Only one machine therefore needs to be taken off-line to inspect/perform maintenance on.

Effective Data Collection Strategy

Answering the following eight questions will allow you to develop an effective strategy for collecting data.

WHAT DO WE WANT TO ACCOMPLISH BY COLLECTING DATA?

WHAT DATA IS NEEDED TO ACHIEVE THIS GOAL?

WHERE IN THE PROCESS SHOULD WE COLLECT DATA?

WHAT SAMPLING SCHEME SHOULD WE USE?

HOW MUCH DATA (how many samples/data points) IS NEEDED?

WHEN/HOW LONG SHOULD DATA BE COLLECTED?

HOW WILL WE RECORD THE DATA?

WHO IS RESPONSIBLE FOR COLLECTING THE DATA?

Once you have developed answers to these questions, review your data collection plan for consistency, completeness, and the potential for gaining commitment to your data collection effort from others involved in the process being observed.

CHECKSHEET

What it is:

A check sheet is a simple form you can use to collect data in an organized manner and easily convert it into readily useful information. With a check sheet, you can:

- Collect data with minimal effort.
- Convert raw data into useful information.
- Translate opinions of what is happening into what is actually happening. In other words, “I think the problem is . . .” becomes “The data says the problem is . . .”

How to use it:

Clearly identify what is being observed. The events being observed should be clearly labeled. Everyone has to be looking for the same thing.

Keep the data collection process as easy as possible. Collecting data should not become a job in and of itself. Simple check marks are easiest.

Group the data. Collected data should be grouped in a way that makes the data valuable and reliable. Similar problems must be in similar groups.

Be creative. Try to create a format that will give you the most information with the least amount of effort.

Tabular Check Sheet Example

Reasons for Misplaced Letters

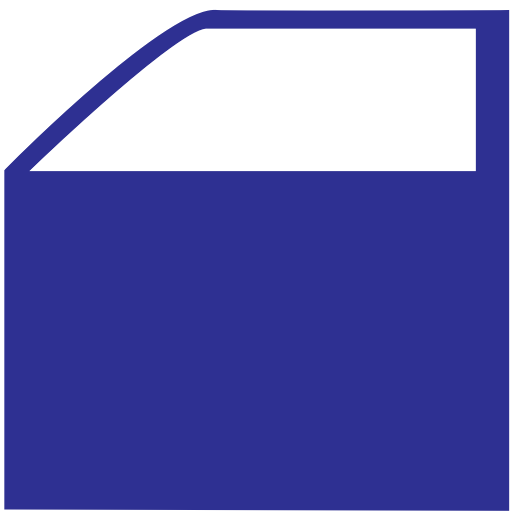
<table>
<tr><th>Defect</th><th>May 6</th><th>May 7</th><th>May 8</th><th>Total Defects</th></tr>
<tr><td>Wrong Mailbox</td><td>|||</td><td>||||</td><td>||||</td><td>11</td></tr>
<tr><td>Wrong City</td><td>||</td><td>𝍸</td><td>𝍸 |</td><td>13</td></tr>
<tr><td>Wrong Zip Code</td><td>𝍸 ||||</td><td>𝍸 ||</td><td>𝍸</td><td>21</td></tr>
<tr><td>Old Office Symbol</td><td>|||</td><td>|</td><td>|||</td><td>7</td></tr>
<tr><td>Total Defects</td><td>17</td><td>17</td><td>18</td><td>52</td></tr>
</table>

Pictorial Check Sheet v.s. Tabular Check Sheet Example

This example shows how a pictorial check sheet can give you much more information than a tabular check sheet.

Defect	***Tally***	***Total***
Scratch	卌 II	7
Chipped Paint	卌 卌 I	11
Tar	卌 II	7
Dent		0
Total		25

Finish Defects on 100 Drivers' Doors (After 25,000 Miles)

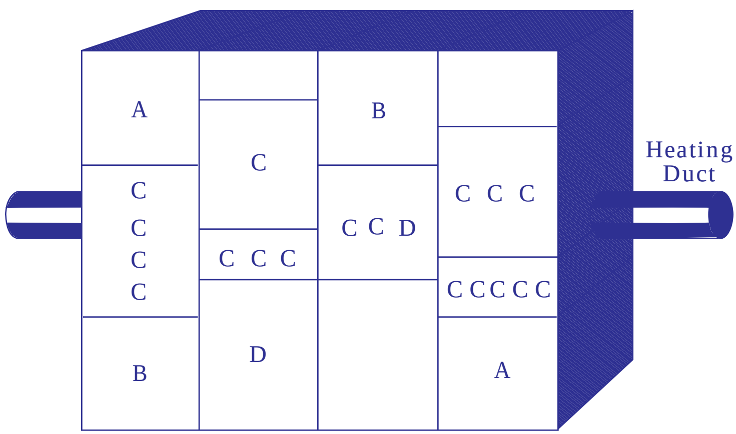


A – Scratch
B – Chipped Paint
C – Tar
D – Dent

Note: A^3 = 3 scratches in close proximity, etc.

Pictorial Check Sheet Example

During testing, the control console in a particular electronic component experienced an unusually high failure rate in some of its black boxes. To help analyze the failures, the managers in the program office developed a pictorial check sheet. After 120 days of testing, the following check sheet showed the types of failures associated with each component.



Control Console Failures

A – Failure to Power Up

B – Failure to Pass Built-In Test

C – Shutdown During Test

D – Unknown Failure

The managers noticed that most of the failures (18 of 24) occurred in boxes along the center of the equipment racks, and that most of these failures were type C, shutdown during test. An inspection of the facility revealed that a heating duct ran directly behind these boxes, and the resulting high temperatures caused the equipment to overheat and fail.

Section 4

BASIC TOOLS FOR ANALYZING DATA

Overview

The tools in this section will allow you to examine your data from several different viewpoints. They will help you organize data so that your process can "talk" to you and tell you what is happening (or not happening). These tools also allow you to package data so that it is easily understood by others. This can be important when you go to sell your proposed solutions to those in decision-making positions.

But, before we jump to solutions, we need to understand some other things these tools can do for us.

What Can These Tools Do For Me?

They are educational

Even those who might not know a lot about a particular process can learn quite a bit merely by using some of these tools. You will learn about your process and the proper application of the tool at the same time.

They serve as a great guide for discussions

Discussing problems or improvement opportunities can often get side-tracked. Using the tools outlined in this chapter will help keep you focused.

They allow you to be proactive in searching out "root causes"

Properly applying these tools will allow you to address the root causes of your problem instead of just the particular symptoms causing you pain. They allow you to take action that is both effective and efficient.

They allow you to convert raw numbers to usable information

Numbers, by themselves, can be meaningless. They need to be collected properly and then packaged so as to make their information clear to all.

They show the level of understanding (or lack of) of your process

They have a wide application to many processes and problems

They are generally easy to use and understand

Key Concepts

There are several key concepts that need to be understood prior to applying the tools to your process. These concepts form the background against which all your data should be viewed.

Statistical Process Control (SPC)

Statistical process control (based on Shewhart's PDCA and control charts) is a process in which you seek to:

* Select and define a process
* Measure that process
* Stabilize that process (eliminate any "special causes" of variation)
* Control that process (reduce any "common causes)
* Continuously improve the process

Basically, you are using numbers (statistics) to understand your process traits and characteristics so you will be able to make it do what you want it to do (control).

Goals of Process Improvement

Your goal should be to increase customer satisfaction and on-time delivery of your products and services. Additionally, you should seek to reduce the cycle time and waste involved in your process producing those services or products.

Variation

No two products or services will ever be exactly alike. This difference is known as variation. Dr. Deming teaches that to produce quality, you must be able to produce outcomes that are predictably uniform while at the same time satisfying customer needs. Reducing or controlling the amount of variation is crucial to improving your process.

"Common Cause" Variation

Common cause variation is due to factors inherent to the process itself. Variation in a process which occurs due to the normal operation of the process, or because of how that process is being managed, it is generally considered to be beyond the control of the individual. Examples might include improper material being provided, poor instructions, etc.

"Special Cause" Variation

Special cause variation occurs as a result of factors external to the process itself. Examples might be a power failure, a machine breaking down, an accident, etc. Special cause variations are exceptions to the normal way things occur.

Tampering

Treating special causes as if they were common causes (or vice versa) is called tampering. It is crucial each of us first understand what the voice of our process (and our customers) are really saying BEFORE we take action. Good intentions and "gut" feelings are not enough. We must use our data, apply the tools show in this section to analyze that data properly for root causes, and then take appropriate actions. Dr. Shewhart has shown that approximately 99% of the causes of variation within a statistically stable process are common causes and can be significantly reduced through informed control. Using data and the tools in this section will provided you the ability to exercise that "informed control" on your process.

Problems, Blame and the 85/15 Rule

TQM is a philosophy grounded in improving a process at every point to maximize the value that process can produce for the customer. It requires us to adopt a new attitude towards our problems. We need to see problems as "areas of opportunity" - to better meet customer needs, eliminate those things causing us "pain," and to increase our effectiveness and efficiency.

Additionally, TQM asks us to forget placing blame and to focus instead on fixing or preventing the problems we have discovered. The 85/15 Rule states that up to 85% of the problems with a process exist due to the process itself and lie within the control of management not the individual worker. Dr. Deming has stated the ration is even higher (96/4).

1-10-100 Rule

Basically, this rule states it is cheaper and easier to fix a problem at the point in a process it occurs. Failure to do so costs you a factor of at least 10 for every step further down the process from you it takes to catch the problem and fix it.

The tools in this section are designed to allow you to discover what your problems are, why they are occurring, how big a problem they are, and how to fix, prevent, and improve your work processes.

FLOWCHART

What it is:

A flowchart is a graphic representation of all the major steps of a process. It can help you:

- Understand the complete process.
- Identify the critical stages of a process.
- Locate problem areas.
- Show relationships between different steps in a process.

How to use it:

Identify the process. Define the start point and finish point for the process to be examined.

Describe the current process. Chart the whole process (i.e., lay out all the steps) from beginning to end. You can use the symbols shown on the next page to improve the clarity of your flowchart, but don't get hung up on symbols.

(Optional) Chart the ideal process. Try to identify the easiest and most efficient way to go from the "start block" to the "finish block." While this step isn't absolutely necessary, it does make it easier to do the next step.

Search for improvement opportunities. Identify all the areas that hinder your process or add little or no value. If you did the optional step, examine all areas that differ from your ideal process and question why they exist.

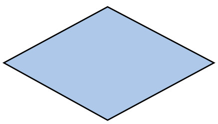
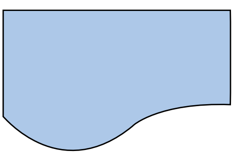
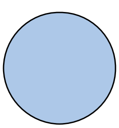
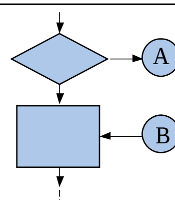
Update your chart. Build a new flowchart that corrects the problems you identified in the previous step.

Helpful hint:

You can put the steps of your process on index cards or sticky-back notes. This lets you rearrange the diagram without erasing and redrawing and prevents ideas from being discarded simply because it's too much work to redraw the diagram.

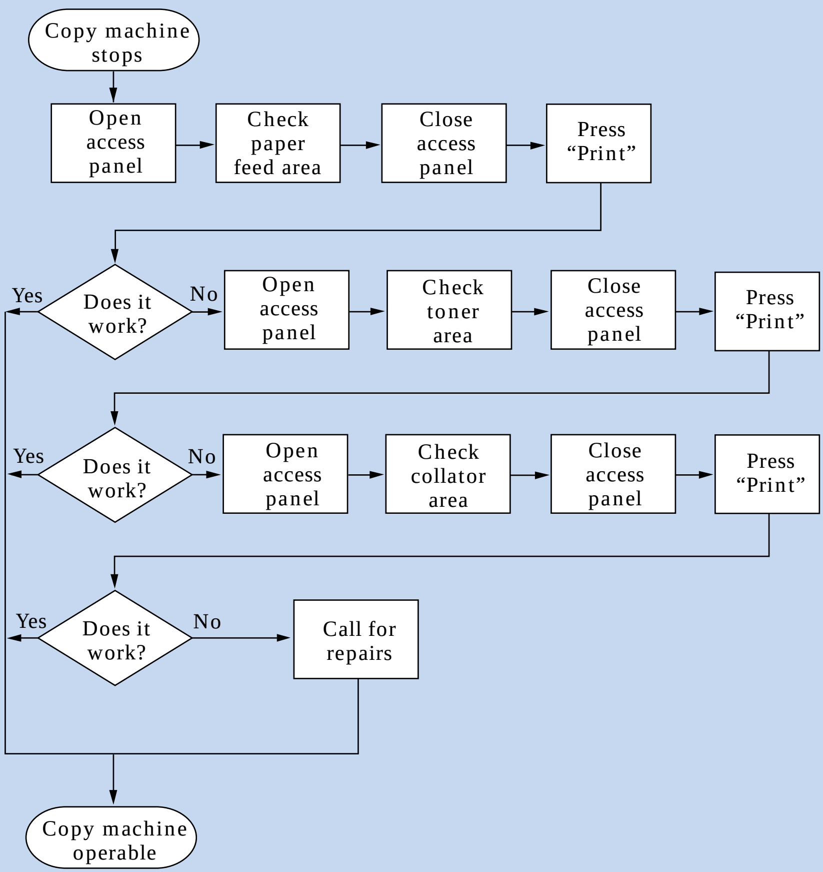
These are standard flowchart symbols. When you are developing a flowchart, especially in a group environment, **the goal is to *chart the process.* Don't waste time debating which shape a symbol should be**. A flowchart that doesn't use these symbols can be just as useful as a chart that does.

Standard Flowchart Symbols

This symbol...	***Represents...***	***Some examples are:***
	Start/Stop	Receive trouble report Machine operable
	Decision Point	Approve/Disapprove Accept/Reject Yes/No Pass/Fail
	Activity	Drop off travel voucher Open access panel
	Document	Fill out trouble report
	Connector (to another page or part of the diagram)	

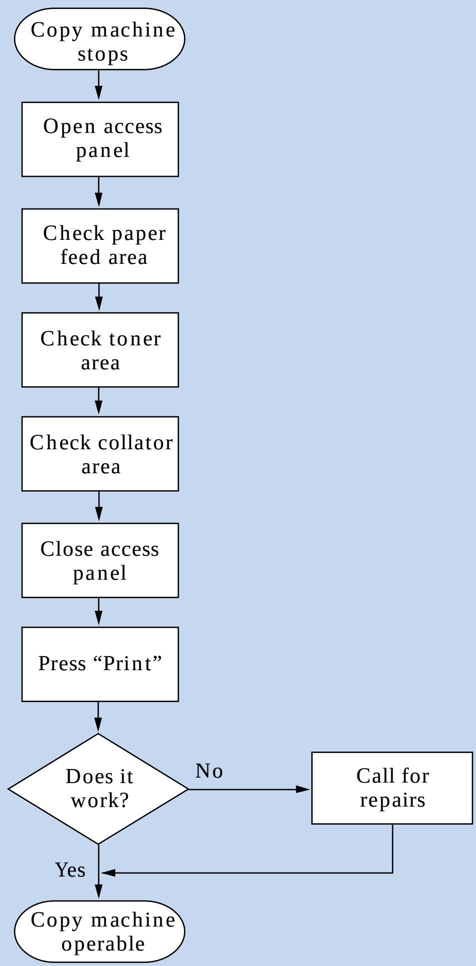
Flowchart Example

Before it was eventually replaced, a copy machine suffered frequent paper jams and became a notorious troublemaker. Often, a problem could be cleared by simply opening and closing the access panel. Someone observed the situation and flowcharted the troubleshooting procedure used by most people.



Flowchart Example (Concluded)

Users usually had to check several locations in the machine before they would find the problem. The next day, this flowchart for a more efficient procedure appeared beside the machine. From then on, there was less frustration and panel slamming when the machine stopped unexpectedly.



CAUSE AND EFFECT DIAGRAM

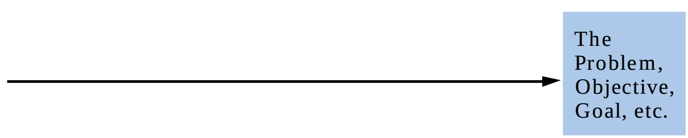
What it is:

Graphically illustrates the relationship between a given outcome and all the factors that influence this outcome. Sometimes called an Ishikawa or "fishbone" diagram, it helps show the relationship of the parts (and sub-parts) to the whole by:

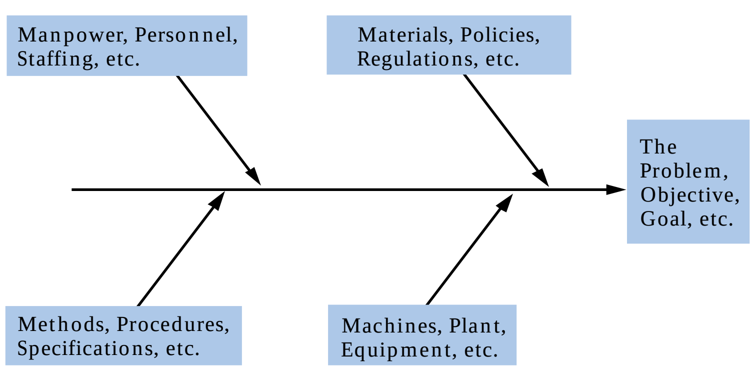
- Determining the factors that cause a positive or negative outcome (or effect)
- Focusing on a specific issue without resorting to complaints and irrelevant discussion
- Determining the root causes of a given effect
- Identifying areas where there is a lack of data

How to use it:

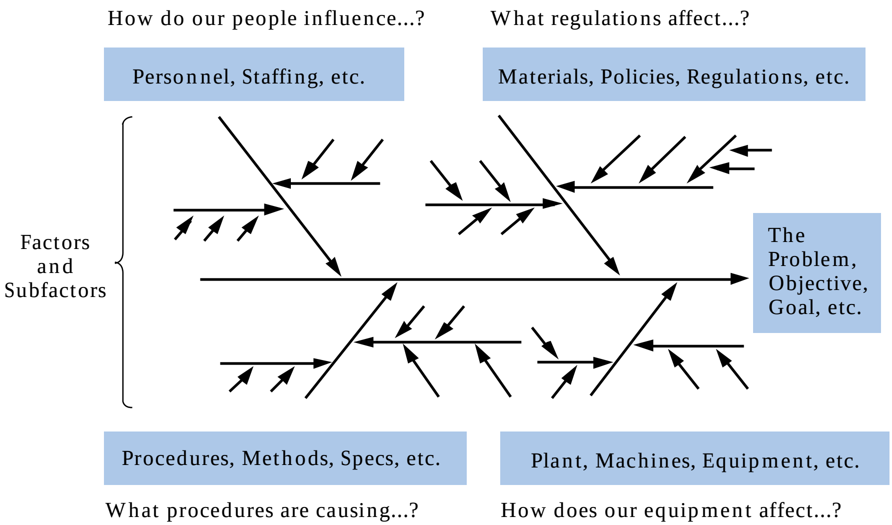
Specify the effect to be analyzed. The effect can be positive (objectives) or negative (problems). Place it in a box on the right side of the diagram.



List the major categories of the factors that influence the effect being studied. The "4 Ms" (methods, manpower, materials, machinery) or the "4 Ps" (policies, procedures, people, plant) are commonly used as a starting point.



Identify factors and subfactors. Use an idea-generating technique from Section 2 to identify the factors and subfactors within each major category. An easy way to begin is to use the major categories as a catalyst. For example, "What policies are causing . . . ?"



Identify significant factors. Look for factors that appear repeatedly and list them. Also, list those factors that have a significant effect, based on the data available.

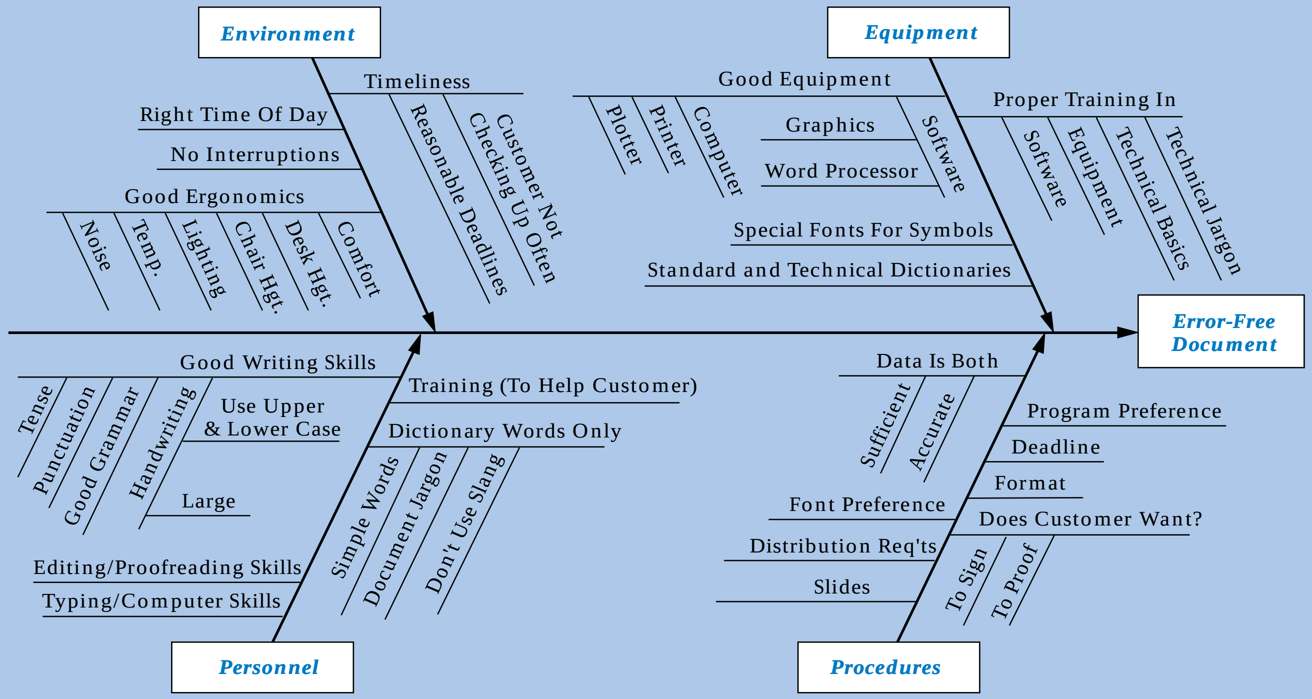
Categorize and prioritize your list of causes. Keep in mind that the location of a cause in your diagram is *not* an indicator of its importance. A sub-factor may be the root cause to all of your problems. You may also decide to collect more data on a factor that had not been previously identified.

Helpful hint:

Consider using a positive effect (an objective, for example) instead of a negative effect (a problem, for example) as the effect to be discussed. Focusing on problems can produce "finger pointing," while focusing on desired outcomes fosters pride and ownership over productive areas. The resulting positive atmosphere will enhance the group's creativity.

Cause and Effect Diagram Example

The publication team for an engineering department wanted to improve the accuracy of their user documentation. As part of a first step, they created a cause and effect diagram to get a picture of what causes a document to be error-free. The diagram below illustrates what this particular team considered important at their first meeting.



PARETO CHART

What it is:

A bar chart used to separate the "vital few" from the "trivial many." These charts are based on the Pareto Principle which states that 20 percent of the problems have 80 percent of the impact. The 20 percent of the problems are the "vital few" and the remaining problems are the "trivial many." A Pareto chart can help you:

- Separate the few *major* problems from the many possible problems so you can focus your improvement efforts
- Arrange data according to priority or importance
- Determine which problems are most important, using data, not perception

How to use it:

Identify the possible problems. Use idea-generation techniques from Section 2 to list all the possible problems in a particular process.

Use existing reports, or collect new data on the process. Be sure the units of measure are consistent throughout your data. Group existing data by consistent units of measure. Select attributes to be charted so that any given occurrence will fall into one ***AND ONLY ONE*** category.

Label the chart. Label the units of measure on the left vertical axis and the categories of problems on the horizontal axis.

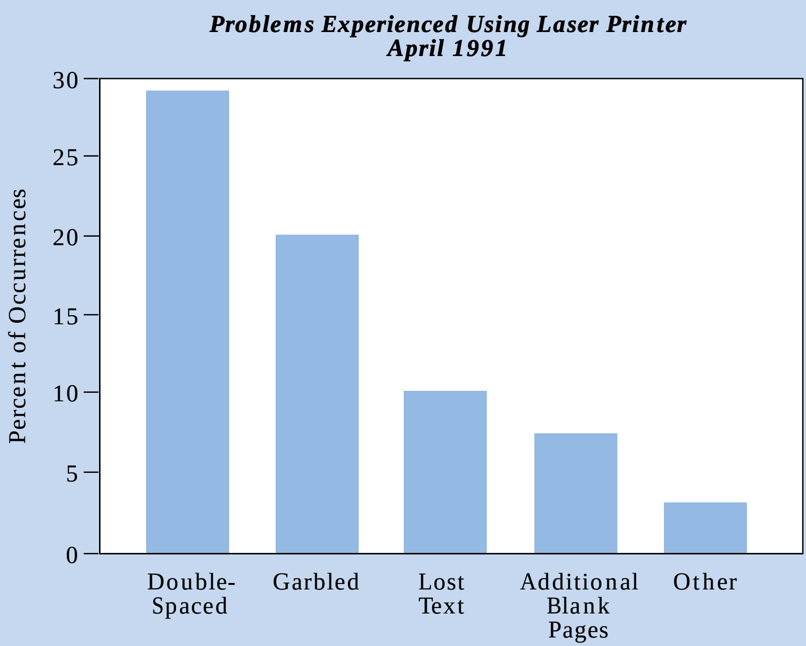
Plot the data. Order the categories according to their frequency (how many), not their classification (what kind). Use a descending order from left to right. Categories that appear infrequently, or in comparatively small numbers, can be grouped together in an "other" category.

(Optional). You can use the right vertical axis to measure the percentage of total occurrences contained within each category.

Points to remember:

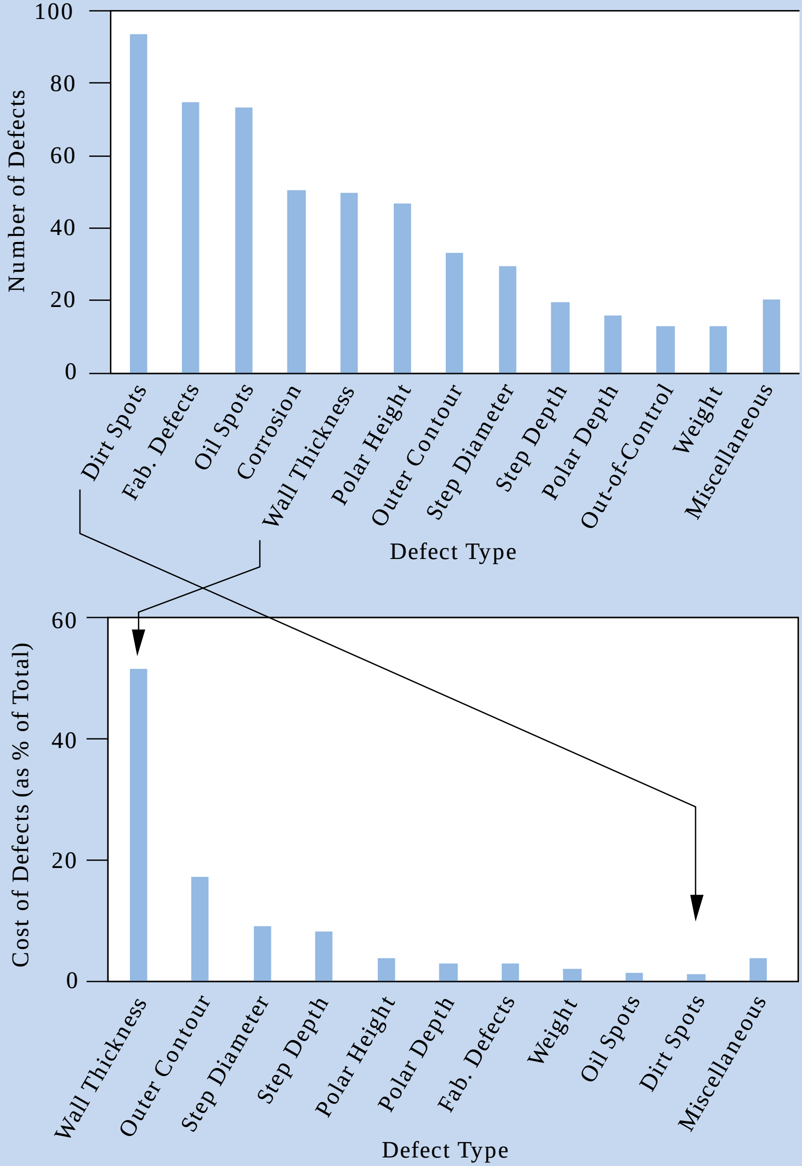
- The measurement units can significantly affect your Pareto chart. In the example shown on page 49, 100 cosmetic-type defects may account for only a fraction of the total cost, while 2 material-type defects may account for a large percentage of the cost. In such a case, you must determine whether cost or number of defects is more important.
- It is essential to use the same units of measure and clearly mark these units on the chart ($, #, %, etc.).
- Make sure that the "other" category doesn't become unreasonably large. If the "other" category accounts for more than 25 percent of your problem, you probably should try to break it down.

Pareto Chart Example



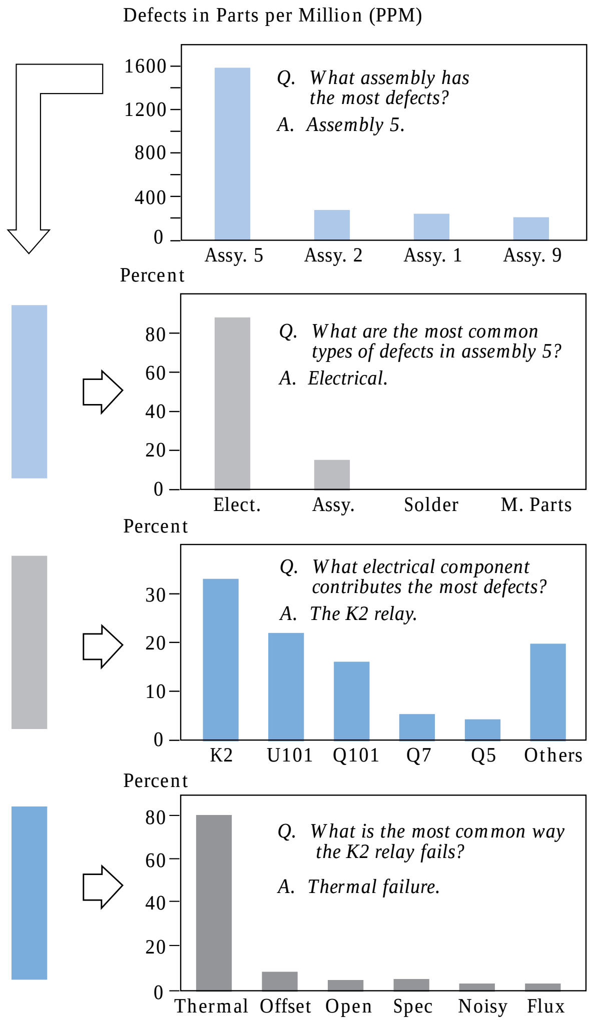
Frequency v.s.. Cost Example

In the following example, the most common defect is dirt spots. However, wall thickness is by far the most costly.



Progressive Analysis

Since Paretos represent data in an ordered and prioritized manner, and do so using discrete data categories, we can use them to progress from general to specific classifications. This technique is known as Progressive Analysis and is show below:



HISTOGRAM

What it is:

A histogram is a bar graph that shows the central tendency and variability of a dataset. Histograms are sometimes referred to as frequency distributions. A histogram can help you:

- Understand the variability of a process.
- Quickly and easily determine the underlying distribution of a process.

How to use it:

Determine the type of data you want to collect. Be sure that the data is measurable, (for example, time, length, speed, etc.).

Collect the data. Collect as many measurable data points as possible. Collect data on one parameter at a time.

Count the total number of points you have collected.

Determine the number of intervals required. Use this table to determine how many intervals (or bars) the graph should have.

If you have this many data points...	***Then use this number of intervals.***
Less than 50	5–7
50–99	6–10
100–249	7–12
More than 250	10–20

Determine the range. Subtract the smallest value in the dataset from the largest. This value is the range of your dataset.

Determine the interval width. Divide the range by the number of intervals. Round your answers up to a convenient value. For example, if the range of the data is 17 and you have decided to use 9 intervals, then your interval width is 1.88. You can round this to 1.9 or 2.0. It is helpful to have intervals defined to one more decimal place than the data collected.

Determine the starting point of each interval. Use the smallest data point value as the starting point of the first interval. The starting point for the second interval is the sum of the smallest data point plus the interval width. For example, if your smallest data point is 10 and the interval width is 2, then the starting point for the second interval is 12. Label intervals along the horizontal axis.

Plot the data. Count the number of data points that fall within each interval and plot this frequency on the histogram. Keep in mind that each data point can appear in only one interval. For example, if your first interval begins with 10.0 and the second with 12.0, then all data points that are *equal to or greater than 10.0 and still less than 12.0* are counted in the first interval.

Points to remember:

- Each data point appears in *one and only one* interval.
- The number of intervals can influence the pattern your data will take.
- Don't expect the histogram to be a perfect bell curve; variations will occur. Ask yourself if the picture is reasonable and logical. But, be careful not to let your preconceived ideas influence your decision unfairly.

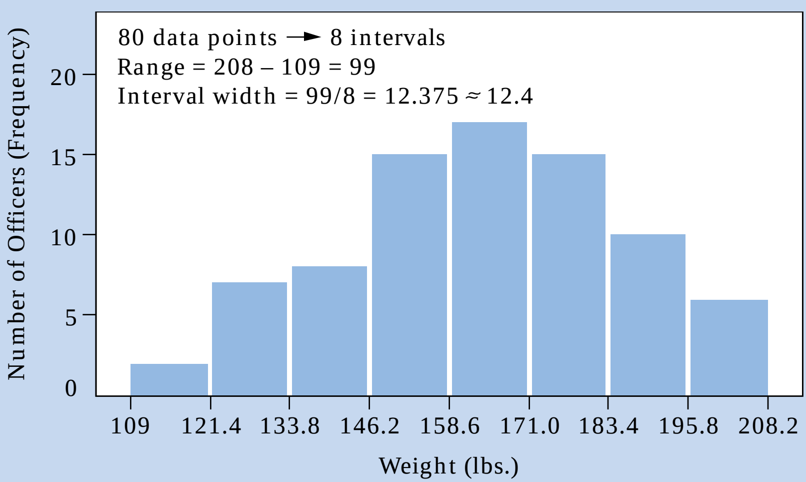
Histogram Example

This table gives the weights of 80 Coast Guard personnel.

Weights of 80 personnel

208	180	139	163	159
155	180	165	149	127
159	171	141	190	159
153	181	180	137	161
115	156	173	165	191
159	109	179	145	144
150	206	166	188	165
127	130	172	180	147
145	150	156	171	189
190	200	208	169	139
130	128	155	185	166
165	187	159	178	169
147	150	201	128	170
189	163	150	158	180
139	149	185	129	169
175	189	150	201	175

A histogram shows the distribution of the data.



SCATTER DIAGRAM

What it is:

A scatter diagram is a graph that reveals a possible relationship between two variables. It can help you:

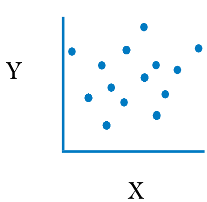
- Identify possible causes of problems
- Recognize that one important variable might be related to another

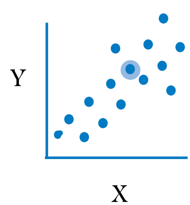
How to use it:

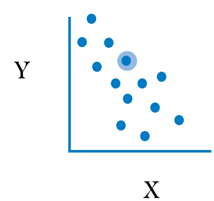
Collect the data in pairs. A data pair consists of two different variables that appear to have a relationship.

Construct the graph. Label the horizontal and vertical axes in an ascending fashion. Ensure that the values on the two axes correspond to the data pairs.

Plot the data. As you plot each point, look for patterns. Circle repeated points. The figures below show how to interpret scatter diagrams.







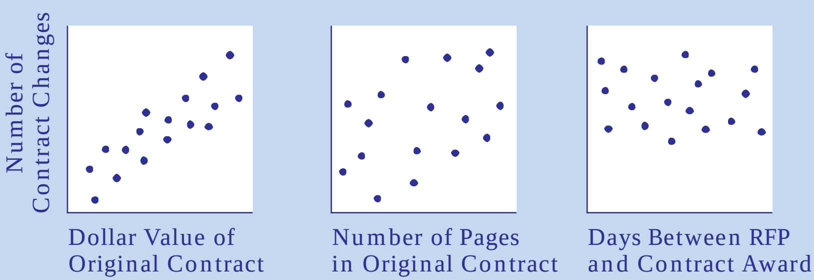
No Correlation:	**Positive Correlation:**	**Negative Correlation:**
(Y does not appear to be related to X)	(An increase in X may be related to an increase in Y)	(An increase in X may be related to a decrease in Y)

Points to remember:

- If there appears to be a relationship between two variables, they are said to be correlated. Both negative and positive correlations, as shown in the figures, are useful for continuous process improvement.
- This method only shows that a relationship exists, not that one variable causes the other. Further analysis using advanced statistical techniques can quantify how strong the relationship is between two variables.

Scatter Diagram Example

A contracting agency wanted to investigate why they had so many changes in their contracts. They used the following scatter diagrams to explore possible relationships.



RUN CHART

What it is:

A run chart is a graph that shows the changes in a process measurement over time. It can help you:

- Recognize patterns of performance in a process
- Document changes over time

How to use it:

Construct the chart. Label the vertical axis with the key measurement of the process being measured.

Collect the data. Collect data for an appropriate number of time periods, in accordance with your data collection strategy.

Plot the data. Plot each data point on the chart.

Calculate and plot the average. This provides a reference for drawing conclusions about individual data points.

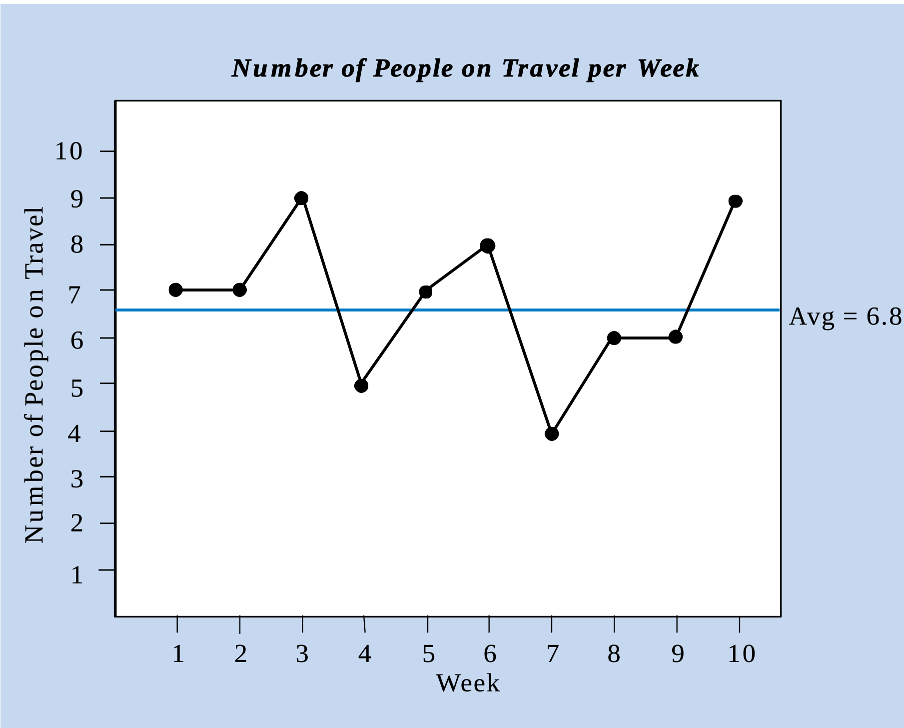
Interpret the chart. Interpret the chart using your knowledge of the process. Two possible signals that the process has significantly changed are:

- Six points in a row that steadily increase or decrease.
- Nine points in a row that are on the same side of the average.
- Other patterns to look for include significant shifts in levels, cyclical patterns and bunching of data points.

Repeat. Recompute the average for subsequent blocks of time, or after a significant change has occurred.

Run Chart Example

The run chart on the following page shows that the average number of people on travel is 6.8, and this has been fairly consistent for the past ten weeks. It is important to recognize the variability (four to nine people per week) that is inherent to this or any other process.



CONTROL CHARTS

Of all the tools for analyzing data, the control chart is the most useful. No other tool captures the voice of your process better. Control charts are used to determine whether your process is operating in statistical control. Until it is, any improvement efforts are, at best, mere process tampering. Basically, a control chart is a run chart (described earlier) that includes statistically generated upper and lower control limits.

The purpose of a control chart is to detect any unwanted changes in your process. These changes will be signalled by*abnormal* points on the graph. Extensive research by Dr. Shewhart indicated that by establishing upper and lower limits at three times the standard deviation of the process (plus and minus, respectively), 99.73% of the common cause variation would fall within these limits.

A process is said , therefore, to be in "statistical control" when the process measurements vary <u>randomly</u> within the control limits; that is, the variation present in the process is consistent and predictable over time.

The upper and lower control limits are not the same as tolerance or specification limits.

Control limits are a function of the way your process actually performs over time. Specification, or tolerance, limits are a function of what your process may have been designed to do and may not necessarily have any direct relationship to the actual performance of the process.

BENEFITS OF CONTROL CHARTS

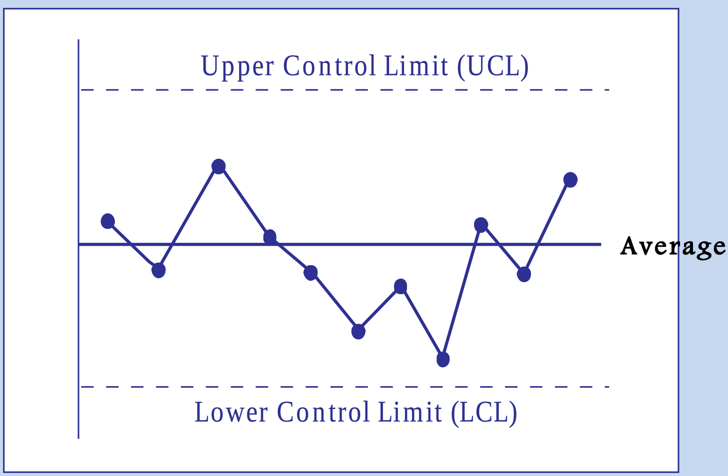
- Help you recognize and understand variability and how to control it
- Identify "special causes" of variation and changes in performance
- Keep you from fixing a process that is varying randomly within control limits; that is, no "special causes" are present. If you want to improve it, you have to objectively identify and eliminate the root causes of the process variation
- Assist in the diagnosis of process problems
- Determine if process improvement effects are having the desired affects

How to use it:

Use the figure on the next page to determine the type of control chart you need.

Control charts use two types of data: variables data and attributes data. In general, if you want to use variables data, you have to take measurements in units such as length, temperature, etc. On the other hand, attributes data requires a good/bad or go/no-go decision and counting (for example, number of defects, percent late, etc.).

Construct the control charts. Once you have determined the type of data to collect, follow the appropriate chart construction techniques described elsewhere in this section.



TYPICAL CONTROL CHART

HOW TO DETERMINE WHICH CONTROL CHART TO USE

STEP ONE: Is a Control Chart the appropriate tool to use?

STEP TWO: Determine type of data **(Attribute or Measurement)?**

STEP THREE: If ***Measurement*** use:

$\bar{X}$-R Chart (if subgroups of five or more)

X Chart (if subgroups of five or less)

If ***Attributes*** (Good/Bad, Discrete Data), use one of the following charts:

If attributes are DEFECTS: Ask, Is a constant sample size used?

If YES: np - Chart If NO: p - Chart

If attributes are DEFECTIVES: Ask, Is constant sample size used?

If YES: c - Chart If NO: u - Chart

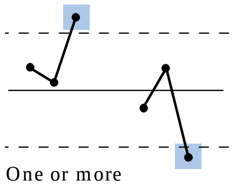
DEFECT: A failure to meet one part of an acceptance criteria

DEFECTIVE: A unit that fails to meet acceptance criteria due to one or more defects

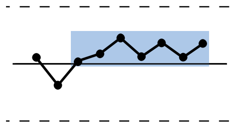
Identify and eliminate any special or assignable causes of variation. To determine whether these causes exist, look for one or more of the seven "signals" shown on the next page. The probability that any of these seven events will occur ***at random*** is very small. That's why they're a signal that something has changed in your process.

Reduce overall variability. After you have eliminated all special causes, try to reduce the remaining variability in your process. This usually requires fundamental changes to the process, and these changes require management assistance. *To achieve continuous process improvement, it's essential to reduce variability.*

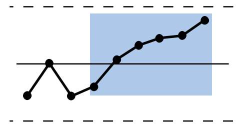
Indications That Special Causes of Variation Are Present



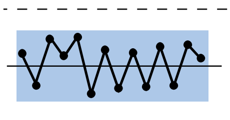
One or more points outside the control limits.



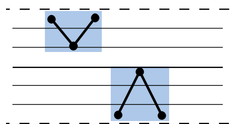
Seven or more consecutive points on one side of the centerline.



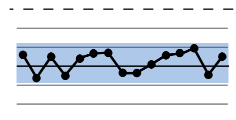
Six points in a row steadily increasing or decreasing.



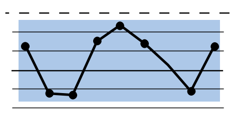
Fourteen points alternating up and down.



Two out of three consecutive points in the outer third of the control region.



Fifteen points in a row within the center third of the control region.



Eight points on both sides of the centerline with none in the center third of the control region.

Common cause variations within a process are, by definition, random. Therefore, any non-randomness indicates the influence of special causes.

Points to Remember:

- Upper and lower control limits are not specification limits. They have a mathematical relationship to the process outputs. Specification limits are based on product or customer requirements.
- Be sure you have selected the correct control chart for the type of data you are collecting.
- Having a data point fall outside the control limits is only one of many different "signals" that indicate a process is out of control. If all the data points *are* within the control limits, be sure to check the other signals that indicate a "special" cause of variation.

- "Special" causes of variation can normally be eliminated by the person(s) who has direct physical control over a process. "Common" causes of variation can normally be reduced only through a fundamental change to the process. Generally, it can be said that common causes are a product of factors which are inherent to a process, while special cause variations are a product of factors which are not inherent to that process.
- There are several types of control charts. Each has its appropriate use and inherent strengths and weaknesses. Becoming familiar with each will allow you to select the best tool for your particular work area or needs.

TYPES OF CONTROL CHARTS AND THEIR USES

X CHART
Shows individual outputs of a process

$\bar{X}$ CHART
Shows average outputs of a process

R CHART
Shows how consistent a process is

P CHART
Shows fraction of defective items for UNEQUAL sample subgroups

np CHART
Shows number of defective items for equal sample subgroups

C CHART
Shows number of defects within each item for equal subgroups

U CHART
Shows number of defects within each item for UNEQUAL subgroups

CHART CONSTRUCTION TECHNIQUES

Measurement Data Control Charts:

Constructing an X Chart

- Collect at least 15-25 data points
- Calculate the moving range for n=2 by subtracting the value of each data point from the one which precedes it. Disregard positive or negative values of each result (the initial data point will have no moving range, since nothing preceded it). The reason for determining the moving range is to minimize the variation within subgroups. The subgroup variation for a sequence of individual values is represented here by the variations from one point to the next.
- Calculate the mean (average) value ($\bar{x}$) for the data points as follows:

$$\bar{X} = \frac{\sum x}{n} = \frac{\text{the Sum of the individual values}}{\text{number of individuals}}$$

- Determine the average value of the range ($\bar{R}$) (the "average moving range") as follows:

$$\bar{R} = \frac{\sum R}{n-1} = \frac{\text{the sum of moving ranges}}{\text{the number of moving ranges*}}$$

*Which is the same as the number of individual values minus 1

- Calculate the control limits as follows:

Upper Control Limit: $\bar{X} + A_1 \bar{R}$

Lower Control Limit: $\bar{X} - A_1 \bar{R}$

FACTOR TABLE
$n = A_1$
2 = 2.659
3 = 1.772
4 = 1.457
5 = 1.290

X CHART CONSTRUCTION EXAMPLE

The following table shows the number of errors that a particular PERSRU recorded per month. Utilizing this data, we shall construct an X Chart.

Month	Nbr of Errors
JAN	25.0
FEB	25.3
MAR	33.8
APR	36.4
MAY	32.2
JUN	30.8
JUL	30.0
AUG	23.6
SEP	32.3
OCT	28.1
NOV	27.0
DEC	26.1
JAN	29.1
FEB	40.1
MAR	40.6

Calculate Moving Ranges:

Month	No. Errors	Moving Range
JAN	25.0	~~~
FEB	25.3	0.3 (25.0 ~ 25.3)
MAR	33.8	8.5
APR	36.4	2.6
MAY	32.2	4.2
JUN	30.8	1.4
JUL	30.0	0.8
AUG	23.6	6.4
SEP	32.3	8.7
OCT	28.1	4.2
NOV	27.0	1.1
DEC	26.1	0 .9
JAN	29.1	3.0
FEB	40.1	11.0
MAR	40.6	0.5
TOTALS:	460.4	53.6

Calculate the mean: $\frac{460.4}{15} = \mathbf{30.69}$

Calculate the mean moving range: $\frac{53.6}{14} = \mathbf{3.83}$

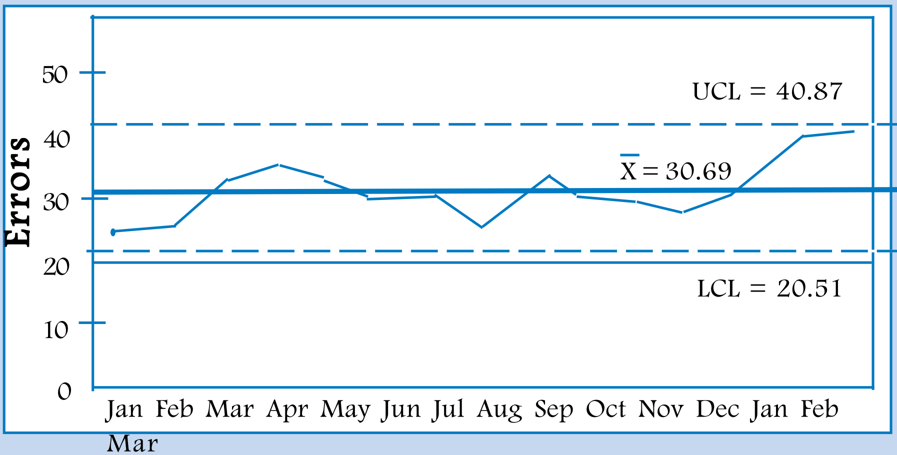
Calculate the Upper Control Limit:

$$30.69 + (2.659)(3.83) = 30.69 + 10.18 = \mathbf{40.87}$$

Calculate the Lower Control Limit:

$$30.69 - (2.659)(3.83) = 30.69 - 10.18 = \mathbf{20.51}$$

Constructing the Chart:



The X Chart did not show any parts outside the control limits for any of the months for which data was available. However, if we apply our other criteria for indicating the presence of special cause variation (see chart on identifying special causes of variation), we find that one indication that a special cause may exist is if there are two out of three consecutive points in the outer third of the control region (area between UCL and LCL) . This criteria seems to apply to the last two data points we have on our chart. Both FEB and MAR may need to be reviewed to see if there is some thing "special" causing the increase in errors (new YN on desk, equipment problems, etc.).

Variables Control Charts:

Constructing an $\overline{X}$ or R Chart

- Collect 10 to 20 subgroups of data, with each subgroup consisting of two or more data points. For example, a subgroup could be a week, and its data points could be days. The size of each subgroup (represented by "n") should remain constant. The total number of subgroups is represented by "K".

- Determine the average ($\bar{x}$) and range (R) for each subgroup as follows:

$$(\bar{x}) = \frac{x_1 + x_2 + \ldots + x_n}{n} = \frac{\sum x}{n}$$

$$R = x_{max} - x_{min}$$

- Determine the overall mean ($\bar{\bar{x}}$) as follows:

$$\bar{\bar{x}} = \frac{\sum \bar{x}}{K} = \frac{\text{thesumofallthesubgroupaverages}}{\text{thenumberofsubgroups}}$$

- Determine the average value of the range ($\bar{R}$) as follows:

$$(\bar{R}) = \frac{\sum R}{K} = \frac{\text{thesumofallthesubgroupranges}}{\text{thenumberofsubgroups}}$$

- Calculate the control limits and centerlines using the formulas and constants in the following two tables.

How To Calculate Control Limits and Centerlines

To calculate the...	*For an $\bar{x}$ chart, use:*	*For an R chart, use:*
Upper Control Limit	$\bar{\bar{x}} + A_2\bar{R}$	$\bar{R}D_4$
Lower Control Limit	$\bar{\bar{x}} - A_2\bar{R}$	$\bar{R}D_3$
Centerline	$\bar{\bar{x}}$	$\bar{R}$

Control Chart Constants

If you have this many observations in a subgroup	For an $\bar{x}$ chart, use this value for	For an R Chart	
		Use this value for	Use this value for
n	A_2	D_3	D_4
2	1.88	0	3.27
3	1.02	0	2.57
4	0.73	0	2.28
5	0.58	0	2.11
6	0.48	0	2.00
7	0.42	0.08	1.92
8	0.37	0.14	1.86
9	0.34	0.18	1.82
10	0.31	0.22	1.78

- Plot the $\bar{x}$ and R charts. These charts should always be used in tandem, because the $\bar{x}$ chart shows the sample-to-sample changes in a process, and the R chart shows the variability within each sample. Recalculate the control limits every 20 subgroups, or if you see a significant change in the process average or variability. Use only the 20 most recent measurements in your calculations.

Basic Tools for Analyzing Data

$\bar{x}$ – R Chart Example

For some reason, lunch expenses became an issue at a consulting firm. It was suggested that these expenses might become a target for budget reductions. To make sure that any decisions about new reimbursement rates would be based on data, rather than impressions, a staff member decided to apply statistical process techniques to the issue. As part of the response, the consultant collected data for ten weeks, as summarized in the table below, and prepared $\bar{x}$ and R control charts.

WEEK	MON $	TUE $	WED $	THU $	FRI $	$\bar{x}$	R
1	4.50	4.60	4.50	4.40	4.40	4.48	0.2
2	4.60	4.50	4.40	4.30	4.10	4.38	0.5
3	4.60	4.10	4.40	4.40	4.10	4.32	0.5
4	4.40	4.30	4.40	4.20	8.00	5.06	3.8
5	4.30	4.30	4.40	4.20	4.30	4.30	0.2
6	4.60	4.60	4.20	4.50	4.40	4.46	0.4
7	4.10	4.30	4.60	4.50	4.20	4.34	0.5
8	4.50	4.50	4.40	4.60	4.40	4.48	0.2
9	4.40	4.20	4.60	4.60	4.20	4.40	0.4
10	4.20	4.20	4.20	4.50	4.20	4.26	0.3
						$\bar{\bar{x}} = 4.45$	$\bar{R} = 0.7$

Variables/Constants used to prepare $\bar{x}$ and R Charts:

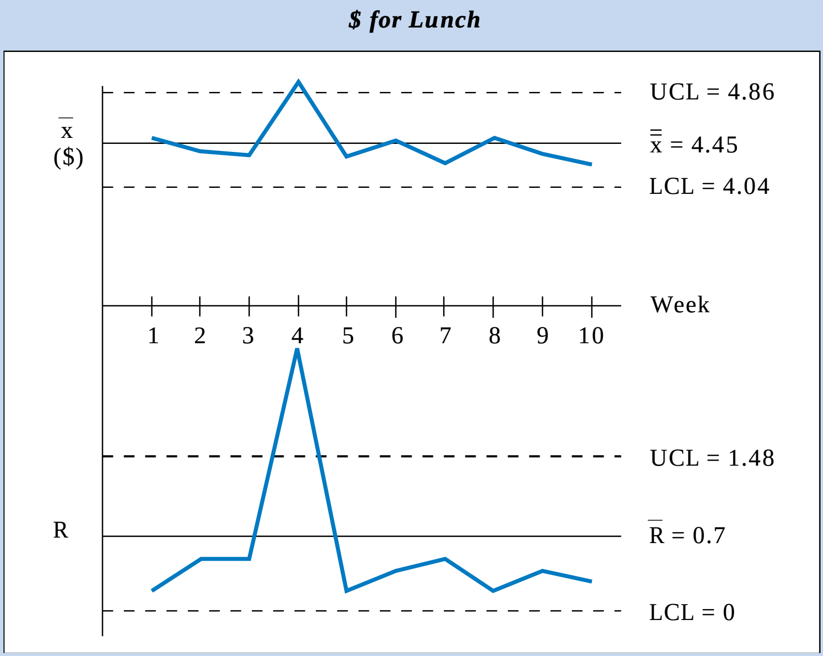
R = the $ range for week $\bar{x}$ = the avg. $ per week   x = the $ for any day

$\bar{R}$ = 0.7 (avg. of weekly ranges)   n = 5 (5 days per week) A_2 = 0.58*

D_3 = 0* D_4 = 2.11*   K = 10 (10 weeks) $\bar{\bar{x}}$ = 4.45 (avg. of weekly avgs.)

*Data obtained from Constants Table on previous page

$\overline{x}$ – R Chart Example (Concluded)



Both the $\overline{x}$ and R chart did show an out of control condition in week 4. Receipts for that week revealed that this was caused by a special farewell luncheon on Friday. After removing this assignable cause, it became evident that lunch was consistently costing $4.00 to $4.50 every day. To reduce this amount, a person would have to make a fundamental change in the "process;" for example, bringing lunch from home, eating at a different place, etc.

The consultant later found out that the farewell luncheon had created an inaccurate impression back at the home office, and the new reimbursement rates would indeed reflect current costs.

Control Charts for Attributes

- Collect 10 to 20 subgroups of data. Each consisting of multiple data points arranged in a rational manner (day, lot, office, etc.). The size of each subgroup is represented by "n".
- Use the following formulas to compute the subgroup statistics and control limits for the type of chart you are using.

p Chart

$$p = \frac{\text{numberofdefectivesinasubgroup}}{\text{sizeofsubgroup(n)}} = \text{fraction or percent defective}$$

$$\bar{p} = \frac{\text{totaldefective}}{\text{totalinspected}} = \text{centerline} = \text{average fraction defective}$$

$$\text{UCL} = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = \text{upper control limit (varies by subgroup)}$$

$$\text{LCL} = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = \text{lower control limit (varies by subgroup)}$$

You can use an average subgroup size to obtain a single set of control limits if:

- The largest subgroup size is less than twice the average subgroup size, and
- The smallest subgroup size is more than half the average subgroup size.

Plot p for each subgroup.

np Chart

$\bar{p}$, n = same as for p chart, except n must be constant

$n\bar{p}$ = centerline = average number of defectives

$$\text{UCL} = n\bar{p} + 3\sqrt{n\bar{p}(1-\bar{p})}$$

$$\text{LCL} = n\bar{p} - 3\sqrt{n\bar{p}(1-\bar{p})}$$

- Plot np for each subgroup.

u Chart

$$u = \frac{\text{number of defects per subgroup}}{\text{number of units per subgroup}}$$

$$\bar{u} = \frac{\text{total number of defects for all subgroups}}{\text{total inspected}} = \text{centerline}$$

$$UCL = \bar{u} + 3\sqrt{\frac{\bar{u}}{n}}$$

$$LCL = \bar{u} - 3\sqrt{\frac{\bar{u}}{n}}$$

- Plot u for each subgroup.

c Chart

c = number of defects per subgroup

$$\bar{c} = \frac{\text{total defects}}{\text{total number of subgroups}} = \text{centerline}$$

$$UCL = \bar{c} + 3\sqrt{\bar{c}}$$

$$LCL = \bar{c} - 3\sqrt{\bar{c}}$$

- Plot c for each subgroup.

Attributes Chart Example

A program director felt that changes to specifications might be excessive. To see whether these concerns were well-founded, the manager tracked the number of times a specification was changed by either an Engineering Change Proposal (ECP) or by a letter from the contracting officer. The table below summarizes the changes for a ten-week period.

Although changes to a specification are not exactly "defects," the changes are attributes data, rather than variables data, and the c chart is appropriate.

Week	1	2	3	4	5	6	7	8	9	10
Number of Specifications Changed	9	7	4	2	4	15	2	3	5	5

$$\bar{c} = \frac{56}{10} = 5.6 \text{ (changes per week)}$$

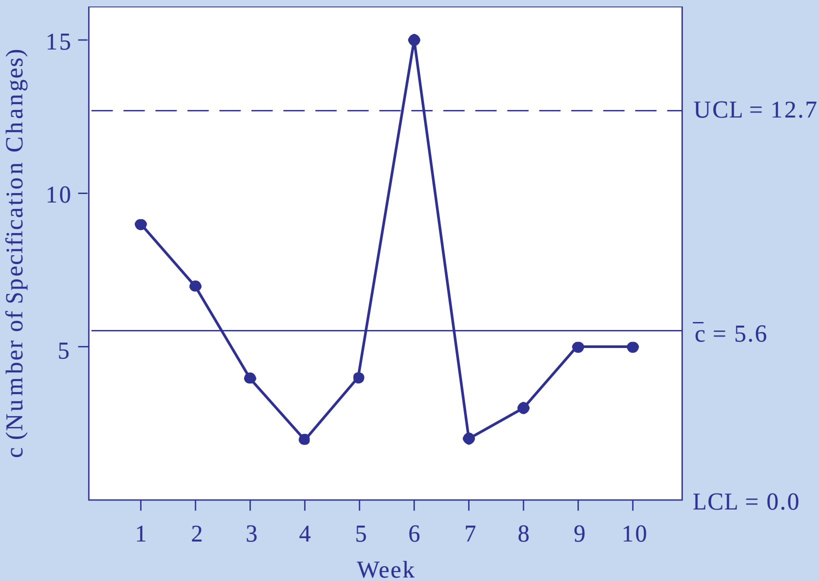
$$UCL = 5.6 + 3\sqrt{5.6} = 12.7$$

$$LCL = 5.6 - 3\sqrt{5.6} = -1.5 \Rightarrow 0$$

$$n = 50 \text{ active contracts}$$

Attributes Chart Example (Concluded)

On a c chart, week six contains a “special cause” for variation. In this case, the special cause was a design review held the previous week. Ten of the fifteen changes in week six resulted from this design review. The program director adopted this control chart as a permanent management tool.



NOTES

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QUICK REFERENCE GUIDE FOR USING TQM TOOLS

IF YOU NEED TO..	THEN TRY THIS TOOL...
Get a lot of ideas about an issue/problem	BRAINSTORMING
Get new ideas/encourage participation	
Discover the root cause(s) of a problem	FIVE WHYS
Show how causes may be related	CAUSE AND EFFECT
Prioritize or reduce a list of items	MULTI-VOTE
	NOMINAL GROUP TECHNIQUE
	PAIRWISE RANKING
Identify driving and restraining forces	FORCE FIELD ANALYSIS
Identify significant influences	
Describe/understand how a process works	FLOWCHART
Identify critical stages of a process	
Determine causes of a particular issue	CAUSE AND EFFECT
Identify root causes	
Identify major problems	PARETO DIAGRAM
Separate and prioritize issues	
Collect data easily	CHECK SHEET
Convert raw data to useful information	
Understand total variability of a process	HISTOGRAM
Understand relationship between variables	SCATTER DIAGRAM
Recognize abnormal behavior in a process	RUN CHART
Document changes over time	
See "special" causes of variation in a process	CONTROL CHART
Know whether a process is stable	

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This guide is for informational purposes and has been distributed to promote a better understanding and use of Total Quality principles, practices, and tools by each member of the United States Coast Guard.

QUICK LOOK INSIDE THIS EDITION

WHERE TO GET INFORMATION ON: